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Title	**A Preliminary Reevaluation of Mexican Spotted Owl Habitat at Los Alamos National Laboratory**
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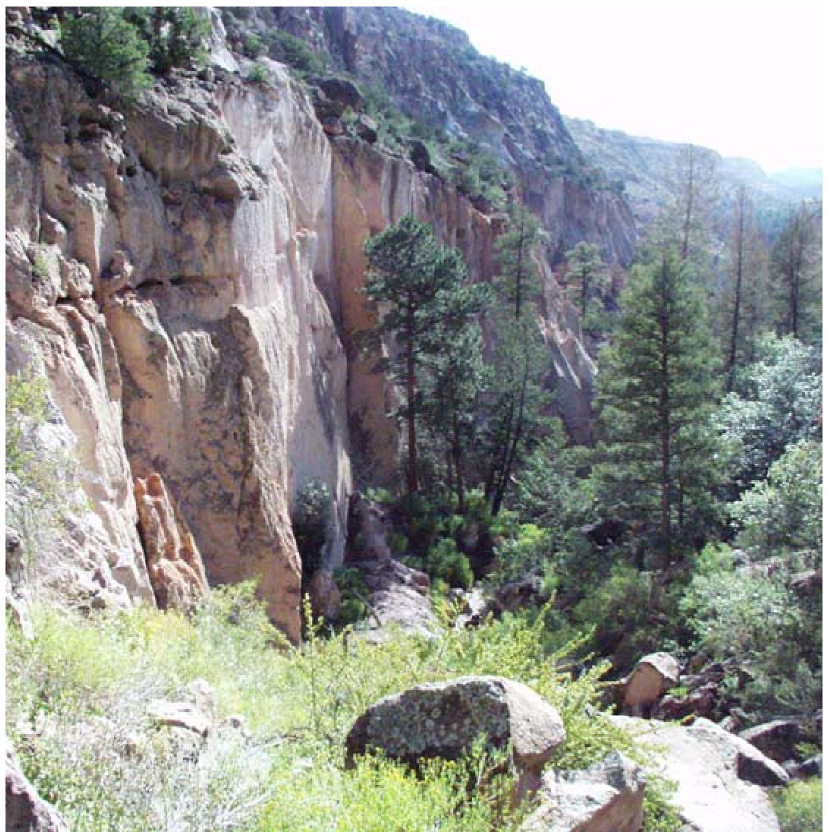

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Contents

Abstract **1**

Introduction **1**

Methods **3**

Study Area 3

Geographic Setting 3

Geologic Setting 5

Study Site Selection 5

Methodology 6

Logistic Regression Model Refinement 6

Vegetation Plots 11

Redelineation of the AEIs 12

Mission Application 13

Results and Discussion **13**

Model Refinement 13

Model Validation 14

Redelineation of the AEIs 15

Sandia–Mortandad AEI 15

Los Alamos Canyon AEI 19

Water Canyon–Cañon de Valle AEI 22

Future Work **25**

Acknowledgments **25**

Literature Cited **25**

List of Tables

Table 1. Regression Coefficients. 13
Table 2. Study Site Scores from Sandia–Mortandad AEI. 17
Table 3. Study Site Scores from Los Alamos Canyon AEI. 19
Table 4. Study Site Scores from Water Canyon–Cañon de Valle AEI. 22

List of Figures

Figure 1. General Area Map. 4
Figure 2. Land Cover Subtraction Map of Sandia–Mortandad AEI. 7
Figure 3. Land Cover Subtraction Map of Los Alamos Canyon AEI. 8
Figure 4. Land Cover Subtraction Map of Water Canyon–Cañon de Valle AEI. 9
Figure 5. Study Plot Locations in Sandia–Mortandad AEI. 16
Figure 6. Proposed Core and Buffer Boundaries for Sandia–Mortandad AEI. 18
Figure 7. Study Plot Locations in Los Alamos Canyon AEI. 20
Figure 8. Proposed Core and Buffer Boundaries for Los Alamos Canyon AEI. 21
Figure 9. Study Plot Locations in Water Canyon–Cañon de Valle AEI. 23
Figure 10. Proposed Core and Buffer Boundaries for Water Canyon–Cañon de Valle AEI. 24

A Preliminary Reevaluation of Mexican Spotted Owl Habitat at Los Alamos National Laboratory

Abstract

The purpose of this study was to implement a predictive, vegetation-based habitat model for Mexican spotted owl [*Strix occidentalis lucida* (MSO)] habitat at Los Alamos National Laboratory (LANL). The LANL is located on the eastern edge of the Jemez Mountains on the Pajarito Plateau in north-central New Mexico. The MSO, one of three subspecies of spotted owls, is found in southern Utah and Colorado, in all of New Mexico and Arizona, and in parts of northern México. The MSO is distributed discontinuously throughout its range, with its distribution largely restricted to montane forests and canyons. The MSO was listed as "threatened" under the Endangered Species Act (ESA) on 15 April 1993. At LANL, compliance with the ESA is managed on behalf of the Department of Energy (DOE) and the National Nuclear Security Administration (NNSA) using a site-wide threatened and endangered species habitat management plan (HMP). This research is driven by the need to continue implementing the HMP under changing environmental conditions (e.g., wildfire recovery and drought). The current MSO habitat model at LANL describes habitat based on a combination of topographical features and macro-level vegetation classifications. This research will incorporate a finer scale of vegetation characteristics into the current model for describing MSO habitat. In this preliminary study, three MSO protected areas at LANL, known as areas of environmental interest (AEIs), were examined. Study sites were placed in and around the AEIs to evaluate the habitat for continued protection. Eighteen study sites were examined in three AEIs: Sandia–Mortandad, Los Alamos Canyon, and Water Canyon–Cañon de Valle. Within each study site, six randomly placed vegetation plots were quantified. Eight of the 18 study sites were proposed for removal from the AEIs, eight of the study sites were proposed for retention in the AEIs, and two of the study sites were proposed for addition to the AEIs. The Los Alamos Canyon AEI had a net reduction in size of 88 acres (2.17%) in core habitat and a net reduction in size of 124 acres (3%) in buffer habitat. The Sandia Canyon–Mortandad Canyon AEI had a net reduction in size of 496 acres (42%) in core habitat and a net reduction in size of 439 acres (31%) in buffer habitat. The Water Canyon–Cañon de Valle AEI had a net reduction in size of 318 acres (23%) in core habitat and a net reduction in size of 366 acres (18%) in buffer habitat. Once the new boundaries are established through official consultation with the U.S. Fish and Wildlife Service, any habitat proposed for removal from the AEIs would continue to be surveyed for two years before the newly established AEIs become the primary focus of yearly surveys.

Introduction

The Mexican spotted owl [*Strix occidentalis lucida* (MSO)] was listed as a "threatened" species under the Endangered Species Act (ESA) in 1993 (USFWS 1993), and a recovery plan was developed in 1995 (USDI 1995). The eventual goal of any recovery plan is the removal of the species from the threatened and endangered species list (White *et al.* 1999).

The MSO is a resident raptor species found throughout the mountains and canyons of Arizona, New Mexico, southern Colorado, southern Utah, and northern and central México. Most of these owls reside in a band of mixed coniferous and ponderosa pine/Gambel oak (*Pinus ponderosa* P. & C. Lawson/*Quercus gambelii* Nutt.) forest. In the portion of their range in the U.S., there are substantial subpopulations located in the "Sky Island" mountain ranges of southern Arizona and southern New Mexico (Ward *et al.* 1995). Mexican spotted owls generally nest in trees, although in the northern part of their range (southern Utah and Colorado) they often nest in caves or cliff ledges in canyons and seem to prefer shady habitat with steep cliffs and rocky terrain (Rinkevich *et al.* 1995, Rinkevich and Gutierrez 1996).

The MSO's presence has been recorded in northern New Mexico as far back as the turn of the century and is perhaps more abundant than realized, though still not numerous, with only 49 separate locations known in northern New Mexico (Johnson and Johnson 1985). With its listing in 1993, more effort has been put into searching for locations. Recent territorial occupancy and productivity in the Jemez Mountains is low, and the population is especially vulnerable because it is small and unable to fill its habitat (Johnson 1997). Since 1995, yearly surveys completed at Los Alamos National Laboratory (LANL) have confirmed the existence of a single pair of MSOs (Keller *et al.* 1998) within the seven protected areas.

As part of the site-wide threatened and endangered species habitat management plan (HMP), a topographic-LANDSAT model to describe suitable MSO habitat in and around LANL was developed in 1998 (Johnson 1998). This model differed from other models in that it used a higher resolution than the 7.5-minute digital elevation model data used previously. This model used data provided by the LANL Facility for Information Management, Analysis, and Display. This model was further refined by personnel from the Ecology Group at LANL to include macro-level vegetation communities and allowed for the identification and designation of seven suitable nesting/roosting habitats in and around LANL. These protected areas are called areas of environmental interest (AEIs). Since then, the LANL sought to further upgrade their MSO habitat model.

In 2001 and 2002, examining occupied and unoccupied habitats in the Jemez Mountains of northern New Mexico, Hathcock *et al*. (2003) developed a new MSO habitat model. Using several vegetation characteristics, a multivariate logistic regression model was developed. The binary nature of the response variable in logistic regression allows for the prediction of suitable habitat based on selected characteristics. In addition, a micro-based habitat model such as this can further differentiate between habitats that have only been modeled on a large scale. Logistic regression has been used previously to predict habitat for owl species (Mills *et al.* 1993, Buchanan *et al.* 1999, McComb *et al.* 2002, Swindle *et al.* 1999, Hershey *et al.* 1998, Christie and van Woudenberg 1997, and Loyn *et al.* 2001). However, these studies generally were developed for predicting habitat on a large, landscape scale, many using a geographic information system (GIS). The advantage of this study is that it uses logistic regression to predict habitat on a finer scale for better management of individual owl territories.

Using a model developed in Hathcock *et al.* (2003), a pilot study was recommended to determine the feasibility of applying this logistic regression model to LANL habitat. This pilot study developed the methodology for application to the AEIs at LANL, redelineated new boundaries based on the results, and calculated the percent change of the size of the AEIs.

Methods

Study Area

Geographic Setting

The LANL is situated in Los Alamos County in north-central New Mexico, approximately 60 mi north-northeast of Albuquerque and 25 mi northwest of Santa Fe (Figure 1). The County is approximately 109 mi^2 and is situated in the Jemez Mountains. The western boundary encompasses some peaks of the Sierra de los Valles, the mountainous rim of the Valles Caldera, and portions of the table-like extension on the eastern slopes, known as the Pajarito Plateau. This plateau extends approximately 10 mi from the base of the mountain slopes and ends at the Rio Grande. Narrow, precipitous canyons separated by finger-like mesas dissect the plateau. The LANL is located at the base of the Sierra de los Valles and on portions of the plateau. It comprises 40 mi^2 of the lands within the County.

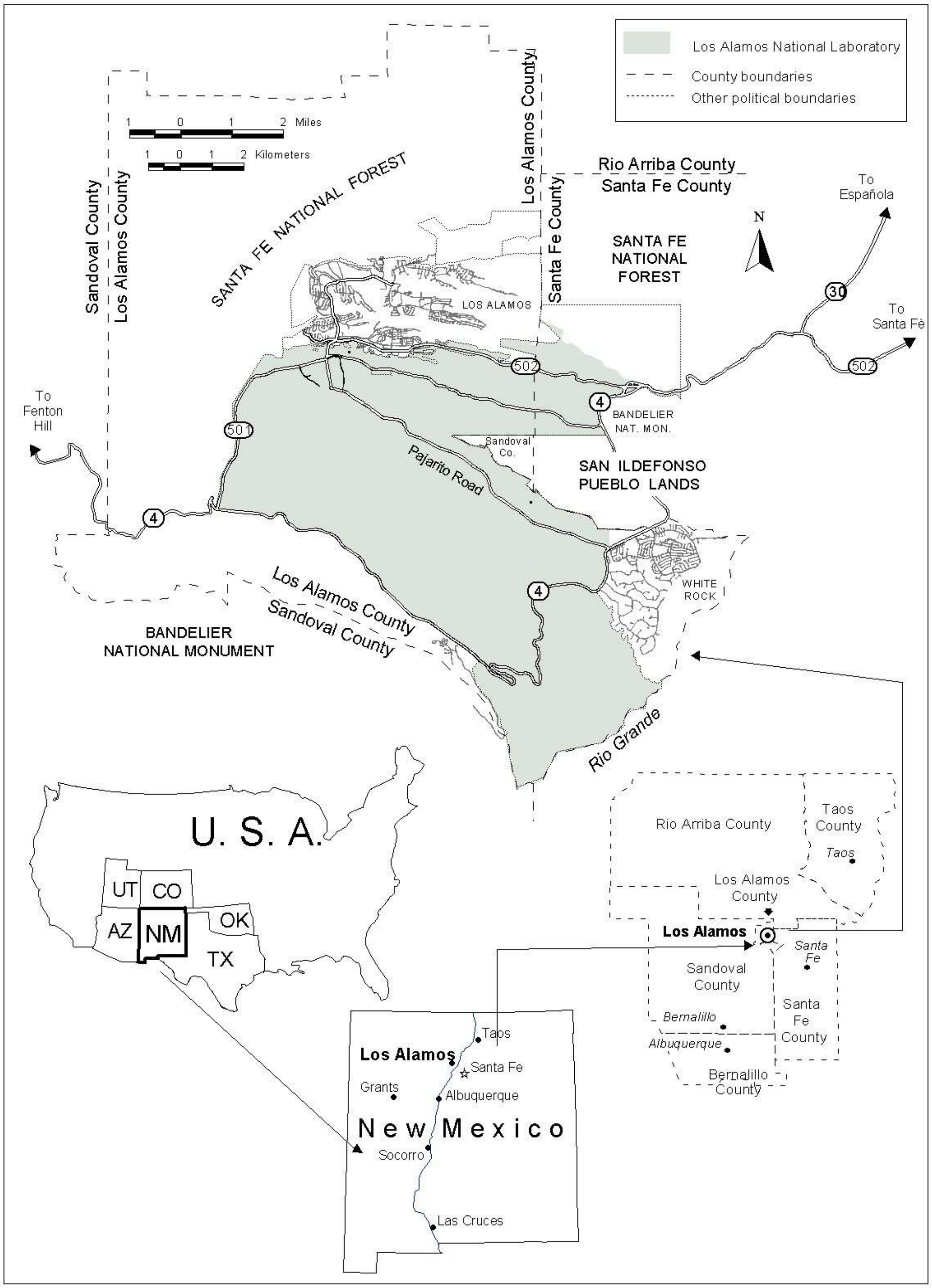

Figure 1. General Area Map.

Because of the rugged topography, most of the facilities are confined to the mesa tops and concentrated in developed technical areas. The remoteness, the lack of development, and the rugged topography provide habitat for a variety of plant and animal species including species listed as endangered or threatened under the ESA.

Geologic Setting

The Jemez Mountains are a remnant of a massive volcano that erupted 1.1 to 1.4 million years ago. Ash from the eruptions laid down 985 ft of welded and nonwelded tuff on the eastern flanks. The rim of the collapsed volcano is called the Sierra de los Valles. The rim has nine peaks including Cerro Grande, Pajarito Mountain, and Caballo Mountain. The tops of the mountains range from 9500 ft to over 11,000 ft in elevation. On the eastern flank of the mountains the Pajarito Plateau is formed from a consolidated ash tuff (Burton 1982).

Study Site Selection

Under the HMP, there are seven AEIs at the LANL delineated for MSO habitat. For this pilot study, three were selected for analysis. Time and budgetary constraints eliminated the possibility of examining all seven AEIs this fiscal year. The three AEIs chosen were Mortandad–Sandia, Water Canyon–Cañon de Valle, and Los Alamos Canyon. Within each AEI, small study sites were selected for analysis. The study sites encompassed the canyon bottoms of the AEIs and were approximately 30 to 35 acres in size each. Within each study site, sampling plots were randomly placed throughout.

The study sites were organized based on two criteria. The first criterion was that we wanted sites placed in areas of potentially marginal habitat within the core. The second criterion was that we wanted sites in areas of potentially good habitat outside of the core. The rationale for the first criterion was to prioritize fieldwork in areas where the AEI would likely be reduced in order to find the appropriate cut-off point. The rationale for the second criterion was to examine areas overlooked in the original AEI delineations for potential habitat in need of protection.

To determine potentially marginal habitat within an AEI, a GIS was utilized. The AEIs were first delineated with input from land classification data derived from a comprehensive land cover map produced in 1997 (Koch *et al.* 1997). Since that land cover classification was first developed, large-scale landscape changes have taken place.

Since the late 1990s, New Mexico has been in a drought condition. The current Palmer drought severity index places northern New Mexico in the extreme drought category (National Oceanic & Atmospheric Administration 2003). Distributions of vegetation across landscapes depend on climate, thus droughts can change landscapes over time and have been implicated in rapid landscape-scale shifts of woody ecotones (Allen and Breshears 1998). Using a new land cover map that was developed in 2003 (McKown *et al.* 2003), the mixed conifer classification from the old land cover map was subtracted from the mixed conifer classification in the new map. The differences, or the areas of mixed conifer decline, were the potentially marginal habitat we were looking for (Figures 2, 3, and 4). Additionally, there have been further changes in the habitat since the new land cover map was developed in 2003. These changes are primarily due to increasing tree mortality from bark beetle infestations and drought conditions. It has been unofficially reported that there is upwards of 80% mortality of *Pinus edulis* over 1.5 meters in height on the Pajarito Plateau due to the drought and bark beetle stress (Balice 2003).

To meet the second criterion, sites were selected based on visual observations by the principal investigators. Areas had to be outside and adjacent to the core as well as meeting the basic requirements for MSO, being in canyons with slopes greater than 40% with mixed conifer present.

Methodology

Logistic Regression Model Refinement

The model developed in Hathcock *et al.* (2003) had to be refined for the current application on LANL. The logistical regression analysis was developed to predict suitable habitat for the MSO based on selected characteristics. Multivariate logistic regression was chosen as the appropriate method for the model because of the presence-absence, or binary, nature of the response variable (Carroll *et al.* 1999). Additionally, logistic regression is preferable to linear discriminate analysis of binary data when the explanatory variables are nonnormal (Press and Wilson 1978), which is true of most of the continuous habitat variables in this study.

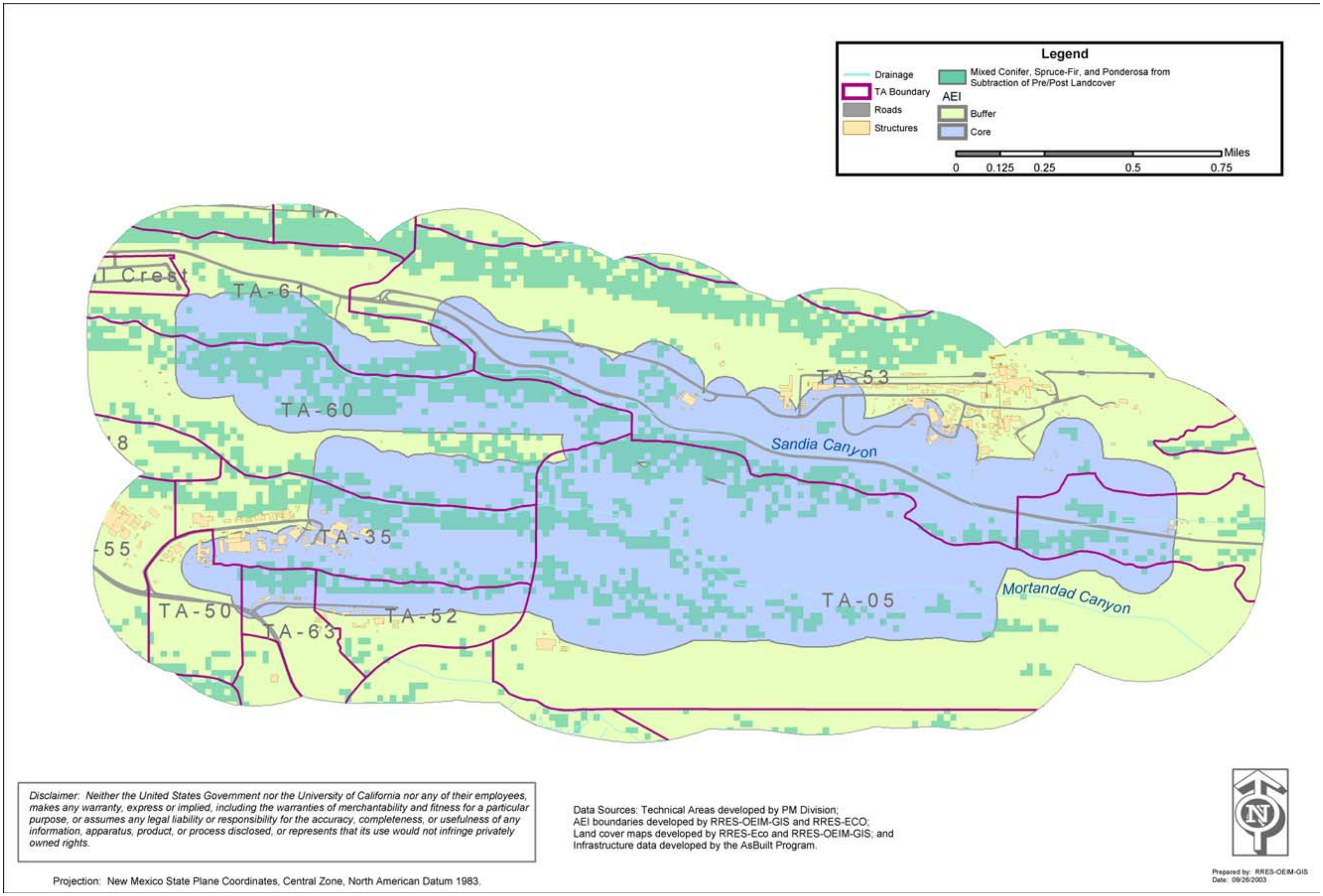

Figure 2. Land Cover Subtraction Map of Sandia–Mortandad AEI.

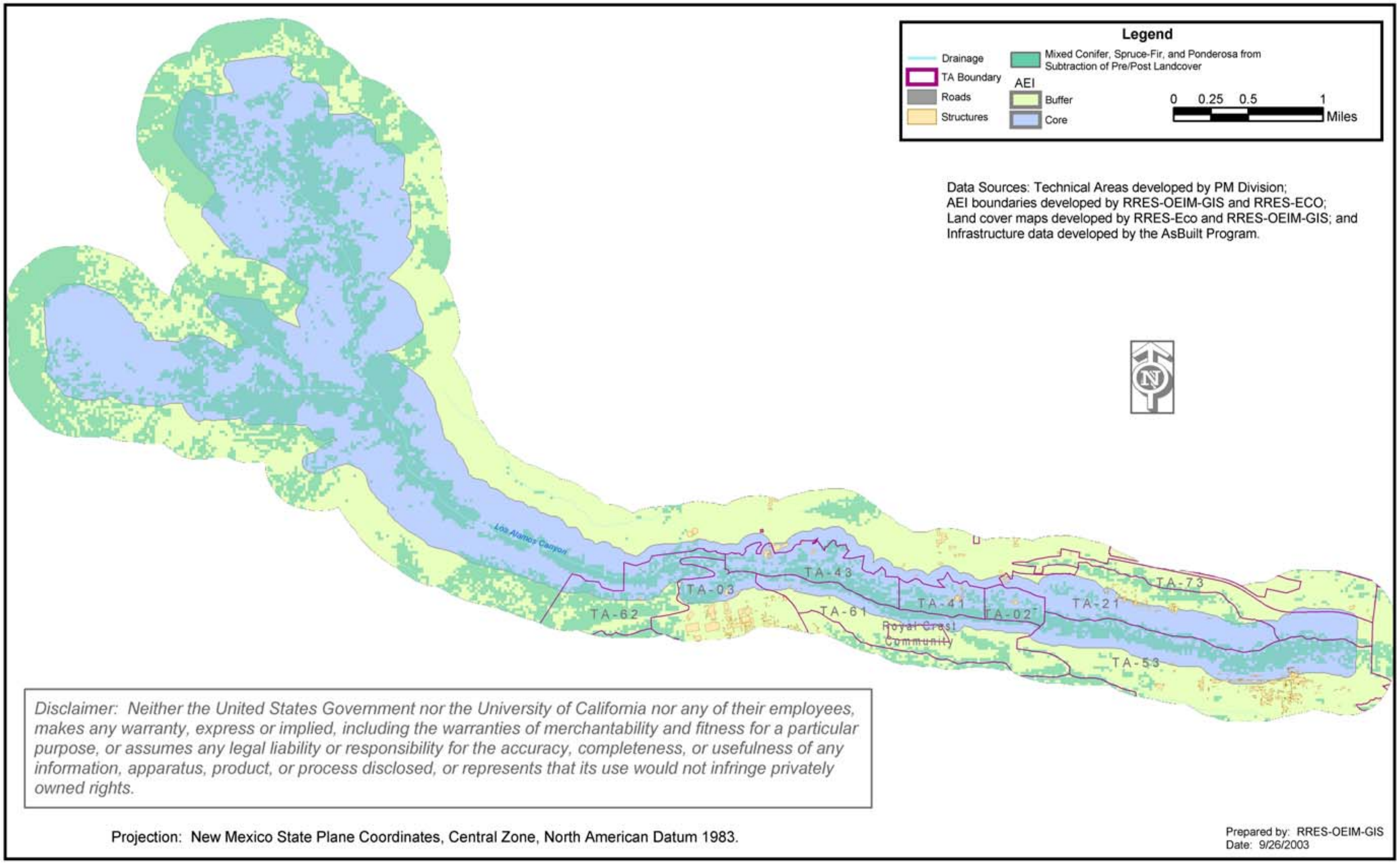

Figure 3. Land Cover Subtraction Map of Los Alamos Canyon AEI.

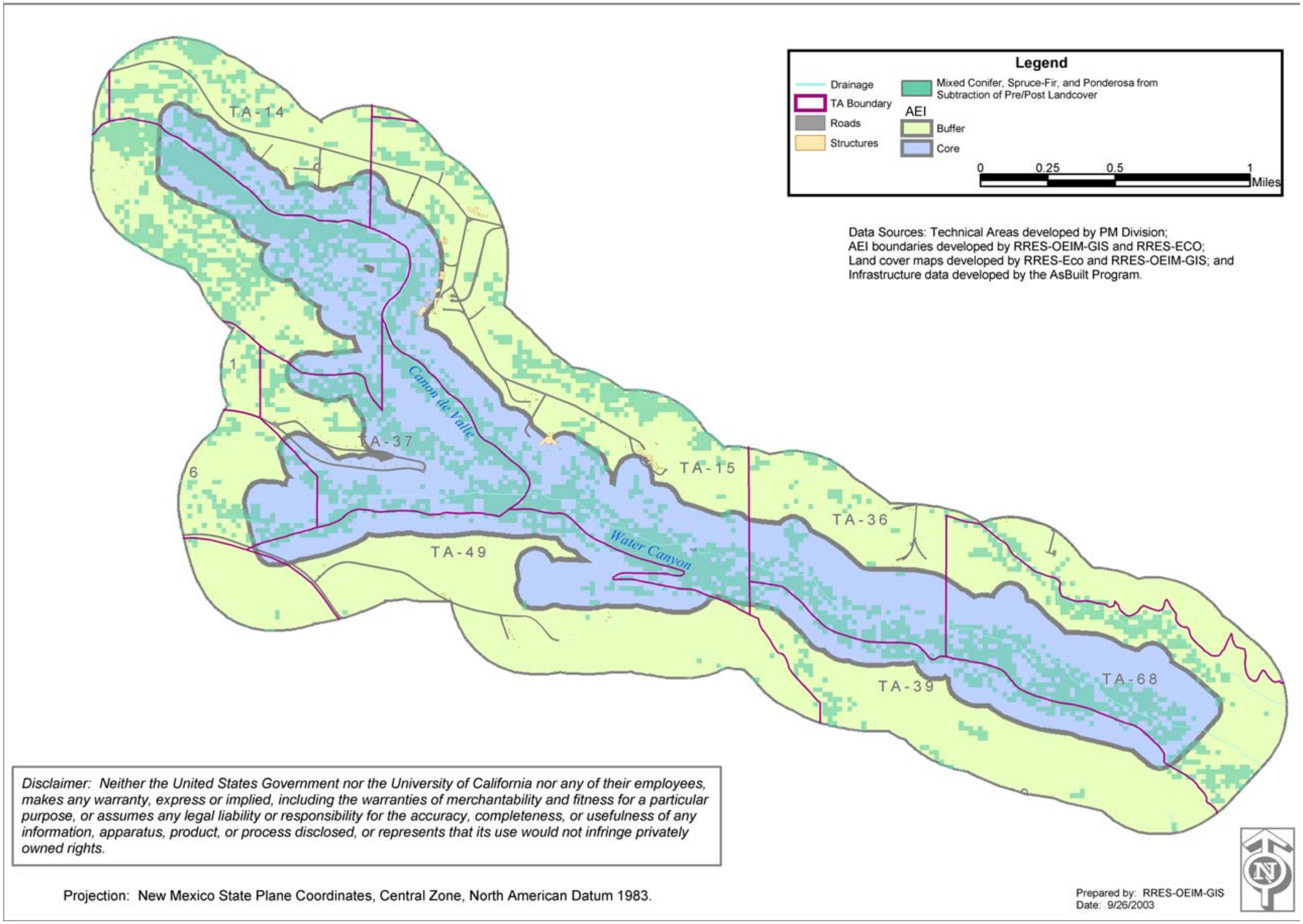

Figure 4. Land Cover Subtraction Map of Water Canyon–Cañon de Valle AEI.

The study took place in the Jemez Mountains of northern New Mexico and data were collected in 12 occupied sites and six unoccupied sites. The original model was based upon 20 habitat characteristics, of those, six were omitted for this refinement. Three herbaceous cover variables were omitted because of a problem in the original study design where the temporal variability, inherent in herbaceous cover estimates, was not taken into account. Two species-specific variables were removed since the species in question did not occur on this side of the Jemez Mountains on the Pajarito Plateau. Lastly, there was a high correlation found between two variables, the total tree diameter at breast height (DBH) per plot and the tree density per plot. They had a Pearson Correlation value of 0.706 ($p<0.05$). One of the two variables had to be removed since they both were explaining similar aspects of the data. The tree density was felt to be a better measure because it held a stronger relationship in the model than the total tree DBH when analyzed separately. The tree density was kept in the analysis and the total tree DBH was the last variable removed.

A multivariate logistic regression analysis was performed with the remaining 14 variables. A forward and backward stepwise function was performed. The selection criteria for the regression model were set to the probability of 0.05 to enter the variable and 0.10 to remove the variable. The best model was selected as defined by the Akaike Information Criterion [AIC (Burnham and Anderson 1998)]. The AIC not only provides a way of estimating the predictive accuracy of fitted models, but also defines a rule for selecting the best model (Forster 2002). The 14 variables used in the model development were as follows:

- the number of snags per plot,
- the average tree height per plot,
- the percent canopy cover per plot,
- the number of shrubs per plot,
- the number of trees per plot,
- the number of tree species per plot,
- average *Pinus ponderosa* height per plot,
- average *Pinus ponderosa* DBH per plot,
- average *Populus tremuloides* height per plot,

- average *Populus tremuloides* DBH per plot,
- average *Pseudotsuga menziesii* height per plot,
- average *Pseudotsuga menziesii* DBH per plot,
- average *Abies concolor* height per plot, and
- average *Abies concolor* DBH per plot.

This model had four assumptions. First, the model was only applicable to mixed conifer habitat. It was developed using only mixed conifer since it is the primary component of MSO habitat. Second, the occupancy status of the study sites used to build the model was assumed to be accurate. No surveys were completed to confirm occupancy. Third, this model was only applicable for the 14 habitat parameters assessed. Fourth, it was assumed that the model accurately captured the variation within the habitat. All statistical analyses were performed with SPSS for Windows© Version 11.0.1 (SPSS, Inc., Chicago, IL).

Vegetation Plots

In this study, six 10- by 10-m plots (100 m^2) were placed randomly within each study site. Randomization of the study plot locations was achieved by using a random point generator within ArcView© Version 3.2a (ESRI, Inc., Redlands, CA). This process generated random points within each study site. These placements ensured that the data collected were representative of the habitat. Within each plot the following characteristics were collected:

- the tree DBH using a standard DBH tape for all trees,
- the tree height using a laser hypsometer for all trees,
- the canopy cover of the plot using a standard spherical densiometer,
- the tree density using count per plot,
- the shrub density using count per plot, and
- the snag density using count per plot.

Tree measurements were sorted and compiled by species. Other ancillary data collected but not used in data analysis included the following: date, time, UTM coordinates, and elevation.

Redelineation of the AEIs

The data from the study sites were input into the logistic regression model. After calculation, the output, or score, was determined. This score was generally a number between zero and one. The logistic function has the shape of an "S" when graphed. On the horizontal axis are the values of the predictor variables, and on the vertical axis are the probabilities. The probabilities, or scores, can become greater than one and less than zero if you move far enough on the X-axis. Such values are theoretically inadmissible. Scores below zero were designated as zero, and scores above one were designated as one.

A score of zero indicated that a habitat was predicted to have a very low probability of sustaining MSO, and a score of one indicated that a habitat was predicted to have a very high probability of sustaining MSO. Study sites with a score of 0.30 or less were considered poor and proposed to be kept out of or removed from the AEI. Study sites with a score of 0.70 or better were considered good and proposed to be retained or added to the AEI. Study sites with a score between 0.30 and 0.70 were marginal and considered on a case-by-case basis, being added or removed from the AEI based on the best biological information available for each area of potential habitat. This entailed an evaluation of all the MSO habitat characteristics present by the principal investigators. Lastly, if marginal habitat occurs between areas of high-quality habitat, these areas will be kept in the AEI in order to keep the core contiguous.

The new core boundaries were delineated with a buffer of approximately 0.5 km to the nearest good habitat, either up or down canyon. Core boundaries were established along readily recognizable geologic features or anthropogenic features in the terrain wherever possible. Since all the AEIs are located in canyons, this would facilitate the ease of identification of core boundaries when in the field.

Changes were mapped with the new core and buffer boundaries, and the percent change was calculated for each AEI examined.

Mission Application

At LANL, compliance with the ESA is managed on behalf of the Department of Energy (DOE) and the National Nuclear Security Administration (NNSA) using a site-wide threatened and endangered species habitat management plan (HMP). This research is driven by the need to continue implementing the HMP under changing environmental conditions (e.g., wildfire recovery and drought). The proposed AEI re-delinations that result from full implementation of this research will be used as the basis for formal ESA Section 7 consultation between DOE/NNSA and the U.S. Fish and Wildlife Service. The HMP scope and implementation procedures will be modified as appropriate based on the results of the consultation.

Results and Discussion

Model Refinement

A total of 14 models were created of varying ability, and selection criteria were calculated to assist in choosing the most robust model. The model chosen had an AIC value of -334.206. This model incorporated seven of the 14 habitat variables and had an R^2 value of 0.605. Thus, this model explained 60% of the variation in the data. The F statistic for the model was highly significant at $p<0.005$.

The unstandardized coefficients and the beta coefficients for this regression model are shown in Table 1.

Table 1. Regression Coefficients.

Regression Model $R^2 = 0.605$	Variable Number	Unstandardized Coefficients	Standard Error	Beta Coefficient
Constant		-2.135	0.386	
Snags Density	1	-0.01852	0.011	-0.143
Average Tree Height	2	0.01449	0.003	0.253
Percent Canopy Cover	3	0.01967	0.005	0.267
Shrub Density	4	0.005073	0.002	0.186
Tree Density	5	0.02484	0.006	0.401
Tree Diversity	6	0.07793	0.026	0.215
Average Ponderosa DBH	7	-0.008692	0.004	-0.123

The unstandardized coefficients were used to develop the regression equation along with the constant to calculate "Y," the dependent variable, or the predicted occupancy value. The regression coefficients for the model are shown in Table 1 and are listed in the equation as 1 through 7.

$$Y = -2.135 - 0.01852_{(1)} + 0.01449_{(2)} + 0.01967_{(3)} + 0.005073_{(4)} + 0.02484_{(5)} + 0.07793_{(6)} - 0.008692_{(7)}$$

Comparisons were not made between unstandardized coefficients. The beta coefficients were used to show which variable had the greatest substantive significance or strongest relationship. The sign in front of the beta tells the direction of the relationship. The strongest beta value was the tree density, which had a strong positive value of 0.401. The average tree height (0.253), percent canopy cover (0.267), the tree diversity (0.215), and the shrub density (0.186) showed strong to moderately strong positive values. These five characteristics weighed heavily in the regression model's ability to predict habitat, which confirms what is in the literature (USDI 1995). Most habitat studies, including the MSO recovery plan, indicate that canopy cover and a dense, diverse, multi-layered forest are important in habitat quality. This mixed-age tree canopy may provide a heterogeneous light environment allowing a greater diversity of herbaceous and graminaceous species and thus a greater prey base. The two negative values were for the snag density (-0.143) and the average ponderosa DBH (-0.008692). These variables were inversely related to the response variable. These negative variables suggest that too many dead trees and too many large ponderosas would negatively affect the ability of a given habitat to sustain MSO.

Model Validation

Two sites in the Jemez Mountains, one occupied and one unoccupied, not used in the original development of the model were used to validate it. The scores calculated were trending in the right direction for predicting the habitat occupancy, though they were not very high in either direction. The occupied habitat scored a 0.623629. This meant that the habitat examined has a 62% chance of containing MSO. The unoccupied habitat scored a 0.410173. This meant that the habitat examined has a 41% chance of containing MSO. The model validation indicates that the regression model functions correctly and the scores were trending in the right direction for predicting occupancy.

Redelineation of the AEIs

Sandia–Mortandad AEI

There were 10 study sites located in the Sandia–Mortandad AEI with a total of 60 vegetation plots quantified (Figure 5). Summaries of the scores are in Table 2. The lower section of Mortandad Canyon scored 0.0 and will be proposed for removal from the AEI. The section of Mortandad Canyon just below the confluence with Ten Site Canyon (a small southern branch of Mortandad Canyon) scored 0.169 and will be proposed for removal from the AEI. The middle section of core in Mortandad Canyon scored a 0.588. This habitat was marginal according to the model, but contains several other topographical features necessary for high-quality MSO habitat (i.e., greater than 40% slope and presence of cliff structure), thus this section will be retained. Upper Mortandad Canyon scored 1.0 and will be retained. A study site in upper Mortandad, just upstream and outside of the core habitat, scored 0.786 and will be proposed for addition to the AEI.

The nearest portion of potential habitat in lower Sandia Canyon was approximately a mile south of the barrow pit, adjacent to West Jemez Road. Two study sites were placed from this point up to the barrow pit. Both scored poorly (0.317 and 0.0) and will be proposed for removal from the AEI. The area adjacent to the barrow pit in Sandia Canyon scored 0.884 and will be retained.

The proposed changes to the AEI have been mapped (Figure 6) and the total change in area was a net reduction in size of 496 acres (42%) in core habitat and a net reduction in size of 439 acres (31%) in buffer habitat. Further studies are warranted to examine habitat further upstream in both Mortandad and Sandia Canyons for possible habitat to add or remove from the AEI.

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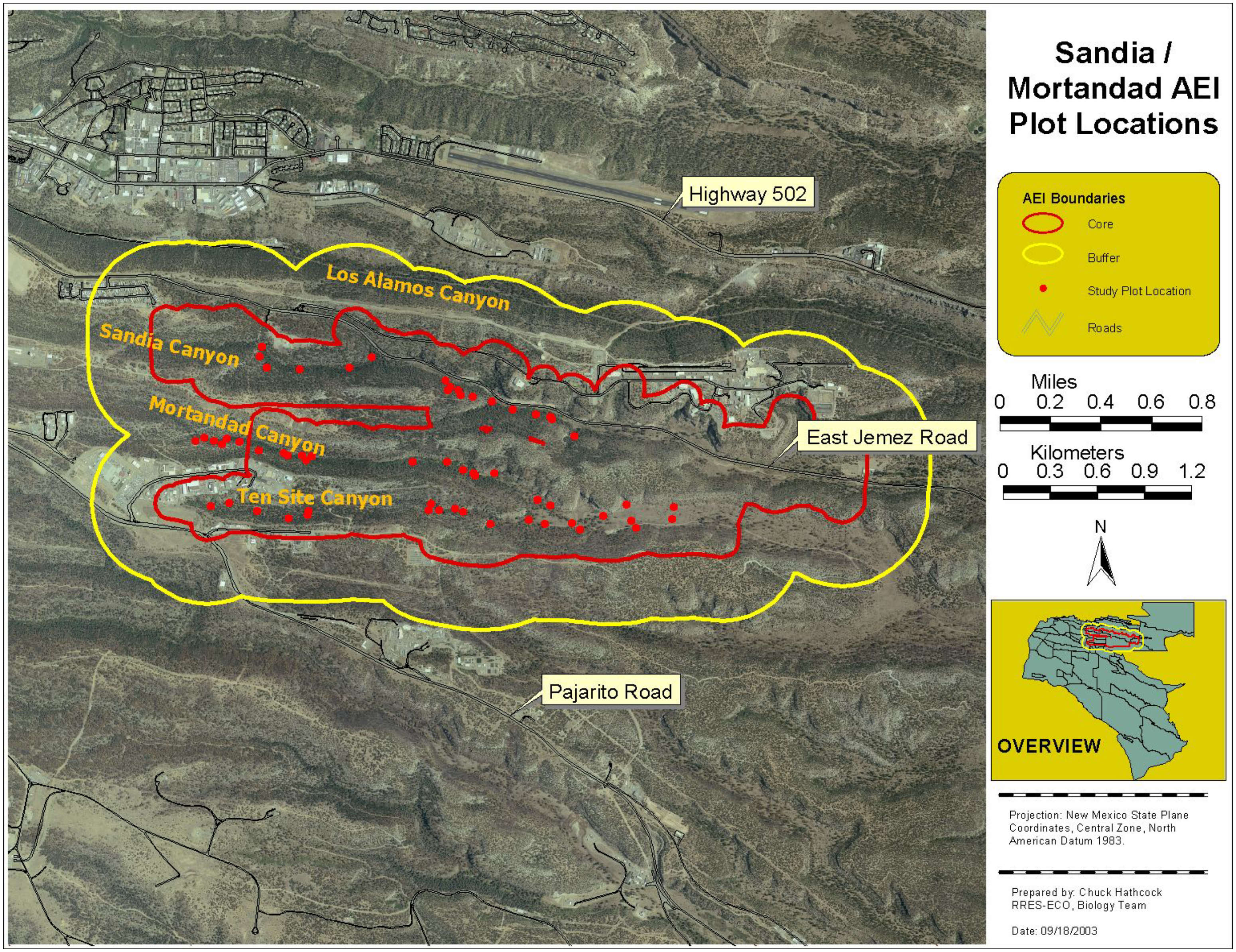

Figure 5. Study Plot Locations in Sandia–Mortandad AEI.

Table 2. Study Site Scores from Sandia–Mortandad AEI.

Regression Equation	Variables	Lower Mortandad	Mortandad Confluence	Middle Mortandad	Middle Sandia Lower	Middle Sandia Upper	Sandia Barrow Pit	Ten Site	Upper Mortandad	Upper Mortandad Outside Core	Upper Ten Site
Constant	-2.135										
Snag Density	-0.01852	1.17	1.33	9	10.17	6.5	6.5	4.33	2.5	2.5	2.67
Ave Tree Ht	0.01449	22.37	62.98	28.64	26.6	27.69	30.13	35.13	24.37	25.29	33.11
Canopy Cover	0.01967	15.2	59.79	80.98	74.95	56.84	83.14	75.69	90.34	78.98	75.21
Shrub Density	0.005073	14.5	30.5	40	37.67	38.5	67	34.67	84.83	62.17	35.83
Trees Density	0.02484	2	3.83	16.83	17.17	9	20	10.33	19.17	18.83	10
Tree Diversity	0.07793	1	1.67	3.17	3.17	2.17	4	2.5	5	3.83	2.83
Ave PIPO DBH	-0.008692	6.4	16.02	1.6	9.63	4.67	9.33	0.71	7.13	3.97	8.1
	Score	-1.388	0.169779	0.588113	0.317289	-0.18872	0.883882	0.403796	1.183011	0.785779	0.354998

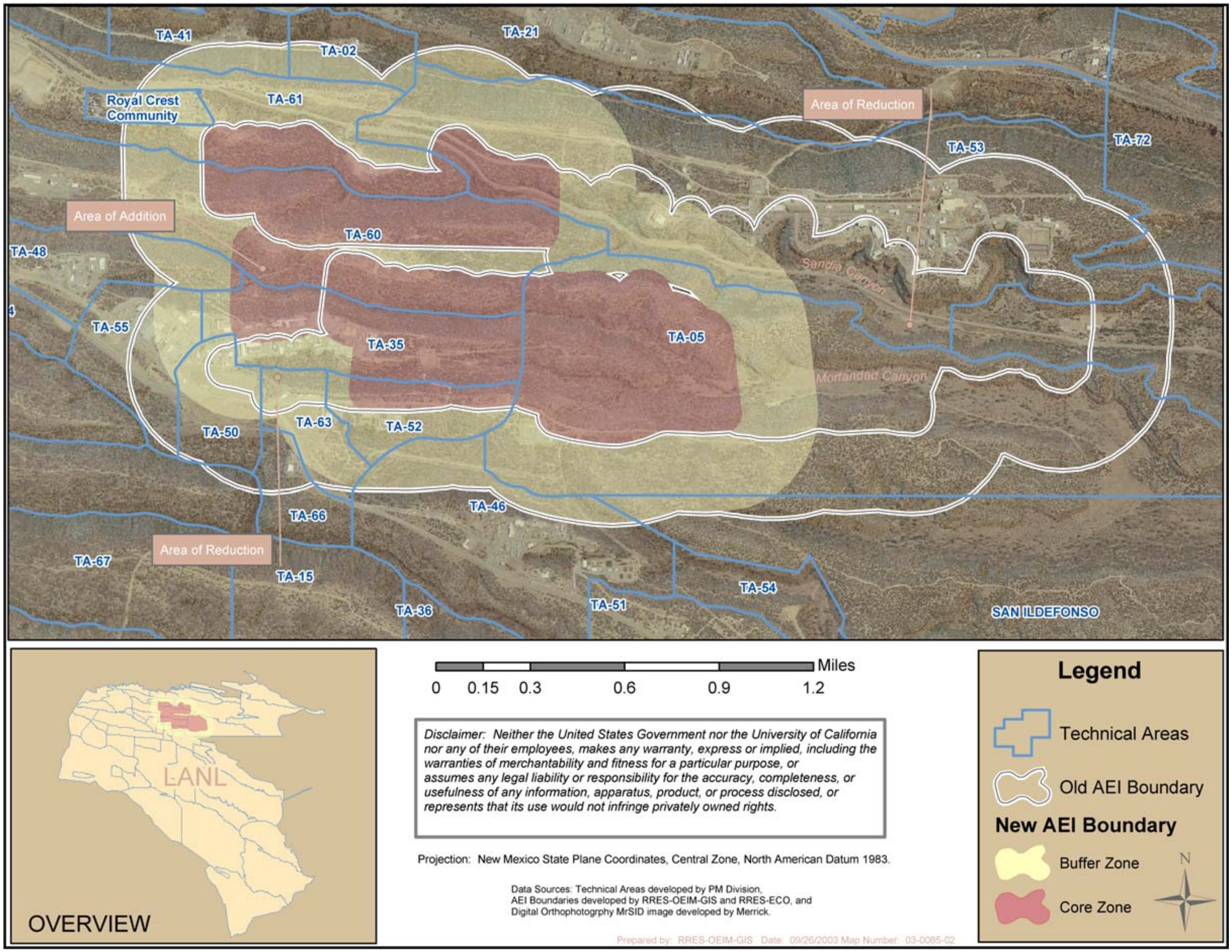

Figure 6. Proposed Core and Buffer Boundaries for Sandia–Mortandad AEI.

Los Alamos Canyon AEI

There were five study sites located in lower portions of the Los Alamos Canyon AEI with a total of 30 vegetation plots quantified (Figure 7). Summaries of the scores are in Table 3. The study site at the bottom of the AEI scored 0.256 and will be proposed for removal from the AEI. The section of Los Alamos Canyon adjacent to and above the confluence with DP Canyon scored a 0.537. This habitat was marginal according to the model, but contains several other topographical features necessary for high-quality MSO habitat, thus this section will be retained. Higher up Los Alamos Canyon scored a 0.726 and will be retained. The small finger-like canyon adjacent to DP Road and outside of the main Los Alamos Canyon channel scored a 0.618. This habitat was marginal according to the model and did not have many of the topographical features necessary for high-quality MSO habitat. Additionally, sections of this small extension of the AEI are set to be transferred ownership from LANL to Los Alamos County soon. Thus, this section will be proposed for removal from the AEI. The study site in lower DP Canyon, before the confluence with Los Alamos Canyon, scored a 0.818. This section of DP Canyon is outside of core and will be proposed for addition to the AEI.

The proposed changes to the AEI have been mapped (Figure 8) and the total change in area was a net reduction in size of 88 acres (2.17%) in core habitat and a net reduction in size of 124 acres (3%) in buffer habitat. Further studies are warranted to examine habitat further upstream in Los Alamos Canyon for possible habitat to add or remove from the AEI.

Table 3. Study Site Scores from Los Alamos Canyon AEI.

Regression Equation	Variables	LA-1	LA-2	LA-21	LA-DP	LA-3
Constant	-2.135					
Snag Density	-0.01852	1.83	0.83	1.67	0.83	2.83
Ave Tree Ht	0.01449	21.61	23.17	32.29	28.17	34.03
Canopy Cover	0.01967	73.39	80.8	76.21	85.18	84.01
Shrub Density	0.005073	21.83	18.5	46.5	48.5	28.67
Trees Density	0.02484	13.83	17.5	9.5	17.5	18.33
Tree Diversity	0.07793	3.5	3.5	3	3.5	3.67
Ave PIPO DBH	-0.008692	6.72	4.45	12.8	7.84	13.63
	Score	0.256444	0.537324	0.617927	0.818653	0.726451

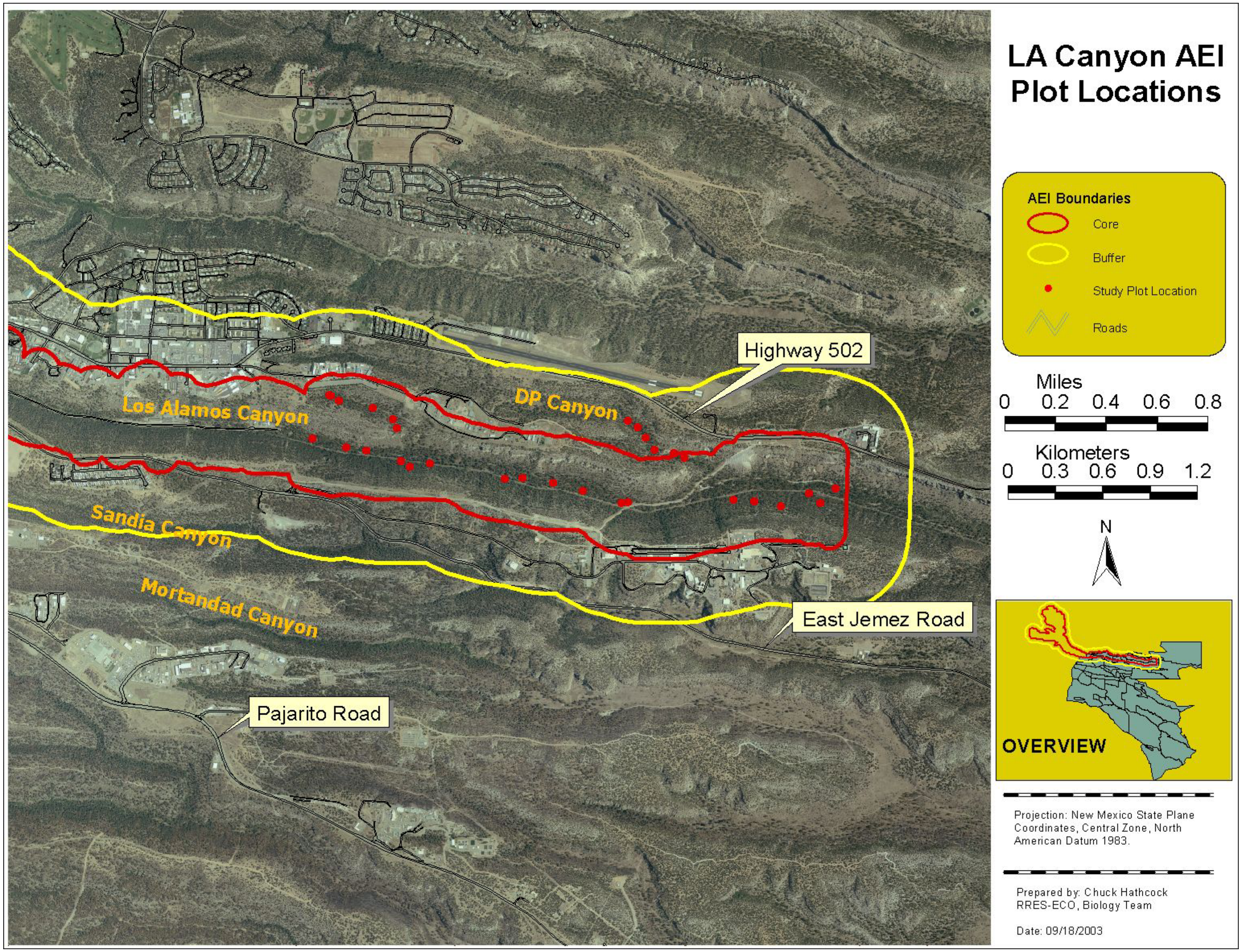

Figure 7. Study Plot Locations in Los Alamos Canyon AEI.

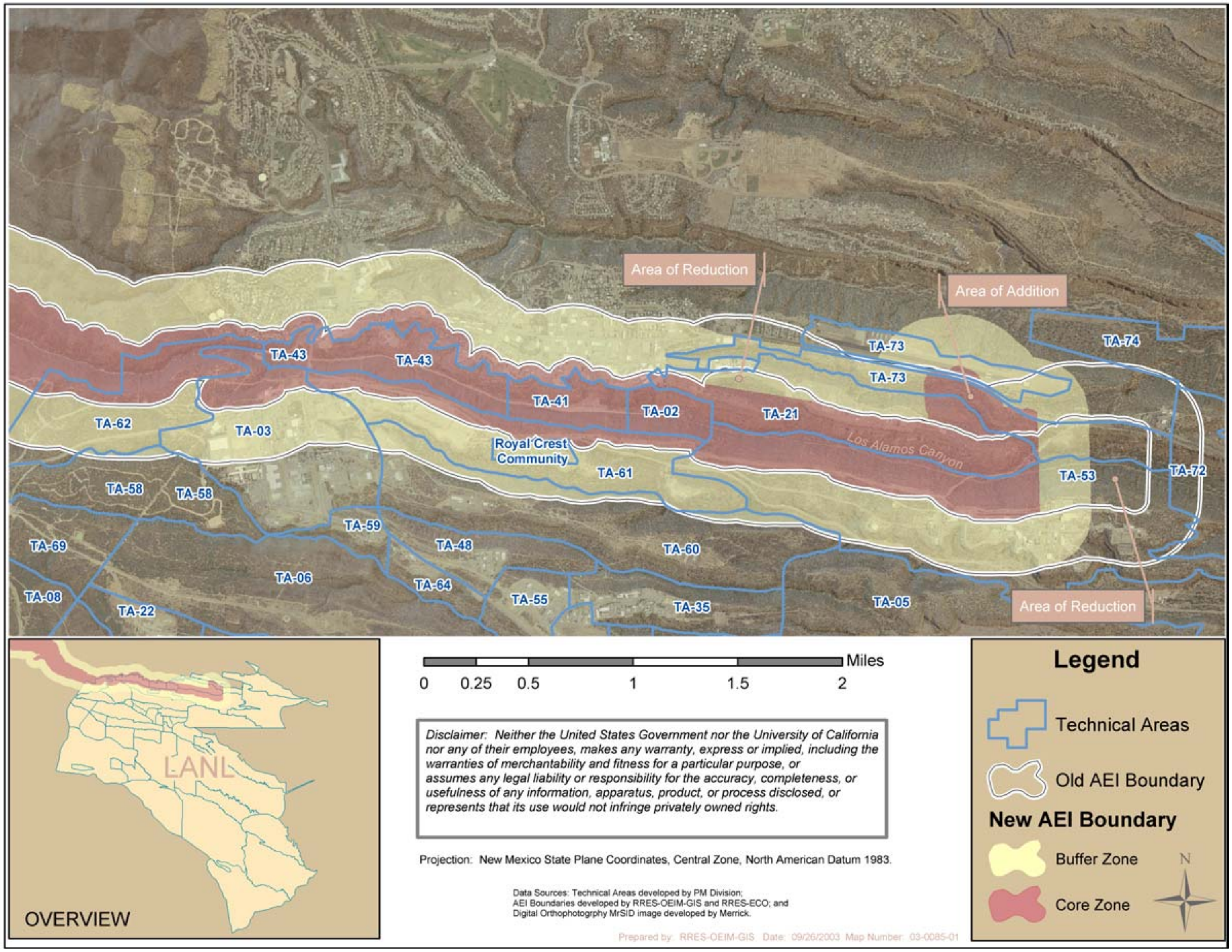

Figure 8. Proposed Core and Buffer Boundaries for Los Alamos Canyon AEI.

Water Canyon–Cañon de Valle AEI

There were three study sites located in lower portions of the Water Canyon–Cañon de Valle AEI with a total of 18 vegetation plots quantified (Figure 9). Summaries of the scores are in Table 4. The study site in the western-reaching finger-like canyon that crossed into Technical Area 49 was not quantified. The six plots were omitted from the study due to the habitat being too poor to sample. There were not any trees in any of the plots and that violated one of the model's primary assumptions of being in mixed conifer habitat. It will be proposed for removal from the AEI. The study site in lower Water Canyon scored 0.087 and will be proposed for removal from the AEI. The second site quantified in lower Water Canyon scored 0.623. This habitat was marginal according to the model, but contains several other topographical features necessary for high-quality MSO habitat (i.e., greater than 40% slope and presence of cliff structure), thus this section will be retained. The proposed changes to the AEI have been mapped (Figure 10) and the total change in area was a net reduction in size of 318 acres (23%) in core habitat and a net reduction in size of 366 acres (18%) in buffer habitat. Further studies are warranted to examine habitat further upstream in Water Canyon as well as in Cañon de Valle for possible habitat to add or remove from the AEI.

Table 4. Study Site Scores from Water Canyon–Cañon de Valle AEI.

Regression Equation	Variables	L-Water-1	L-Water-2
Constant	-2.135		
Snag Density	-0.01852	0.83	1
Ave Tree Ht	0.01449	33.1	27.39
Canopy Cover	0.01967	69.28	76.25
Shrub Density	0.005073	18.5	25.67
Trees Density	0.02484	8.17	19
Tree Diversity	0.07793	2.67	4.83
Ave PIPO DBH	-0.008692	12.57	11.05
	Score	0.087593	0.625738

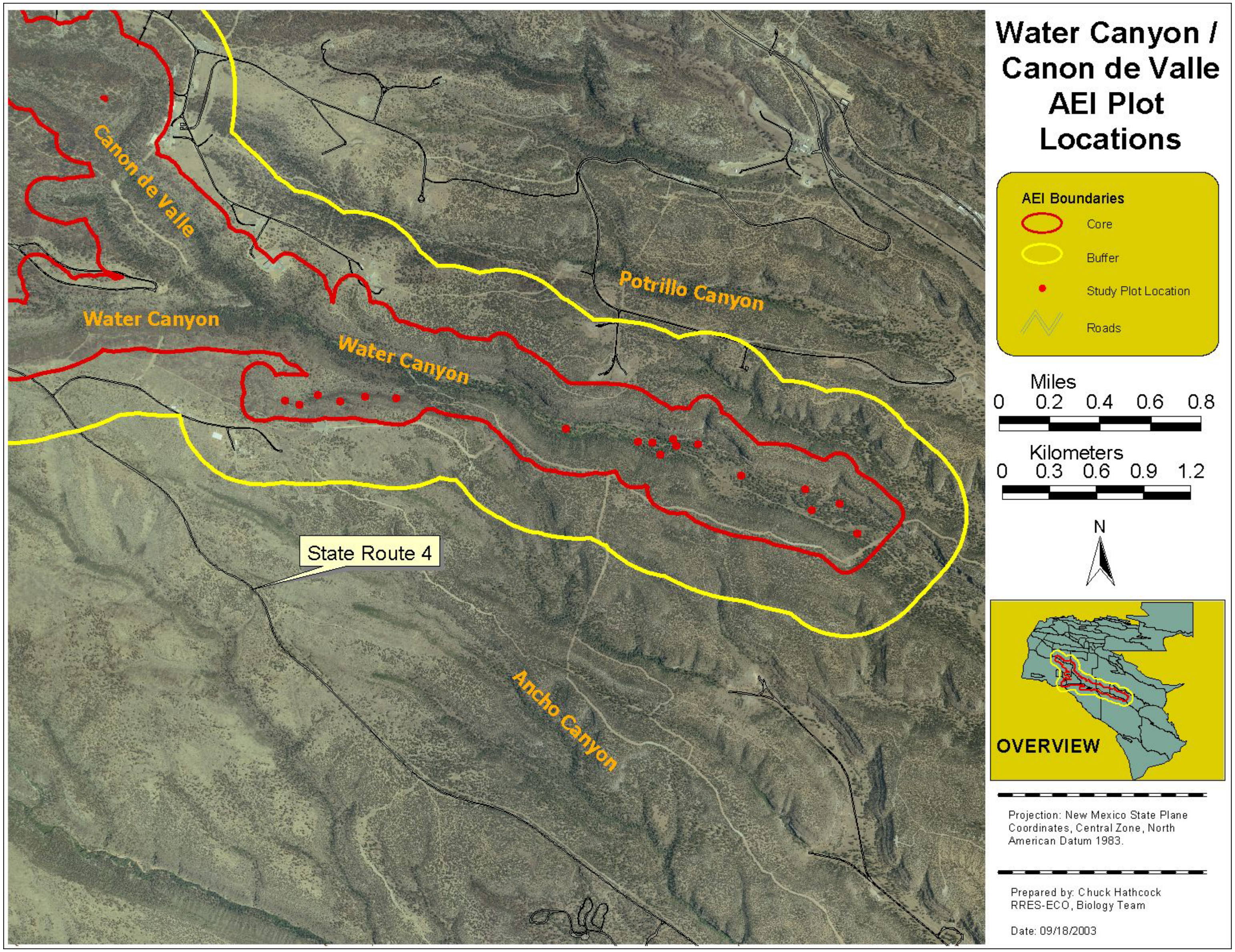

Figure 9. Study Plot Locations in Water Canyon–Cañon de Valle AEI.

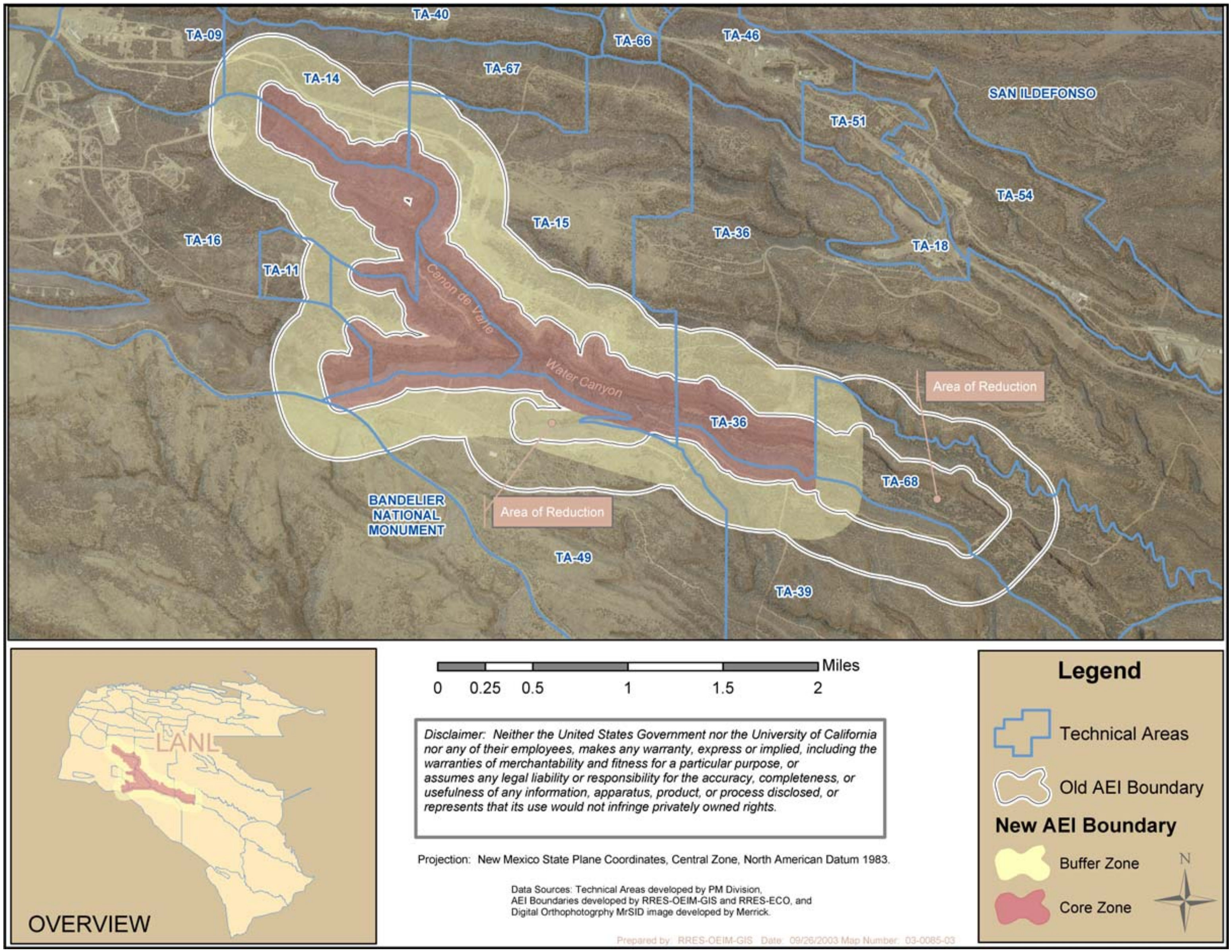

Figure 10. Proposed Core and Buffer Boundaries for Water Canyon–Cañon de Valle AEI.

Future Work

This project has illuminated the need for further work. There are opportunities to remove areas from the AEIs that do not warrant protection as MSO habitat. There are also opportunities to identify areas overlooked by the original landscape analysis and protect them. This work directly supports the goals of the HMP and the MSO recovery plan. In order to ensure accurate and cost effective compliance with the ESA through better management decisions, this research should be implemented in all of the AEIs at LANL. Continuation of the work on the three AEIs in this study should take place, as well as examination of the other four AEIs: Three Mile Canyon, Pajarito Canyon, Pueblo Canyon, and Rendija Canyon.

As part of DOE and NNSA's ESA Section 7 consultation with the U.S. Fish and Wildlife Service for the re-delineation of these AEIs, a provision should include a continuation of the MSO surveys of the habitat proposed for removal for two years after the changes take effect. Another provision of the re-delineation should be to continue to monitor the habitat changes due to factors such as the drought and bark beetle infestation and to develop projects that will determine the effects of these and other factors on the continued quality of the habitat.

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